

# Interdiffusion, Segregation, Ensemble Interactions, and Radiation Induced Effects in InGaAs/GaAs Quantum Dots.

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Ensembles with isolated or non-interacting quantum dots (QDs) can be formed by raising surface energies during growth [1]. This allows large concentration variations in simultaneous growths of InGaAs quantum dots (QDs) by step edge nucleation control on vicinal GaAs (001). QD surface density variations radically affect their optical properties. Interactions between QDs in dense ensembles are seen to blue-shift emission energies, narrow sublevel transition energies, shorten luminescence decay times for excited states, and increase inhomogeneous photoluminescence (PL) broadening [2]. Some of these effects are compared to results obtained in QDs after InGaAs/GaAs thermal inter-diffusion [3] (see Fig. 1). These changes are attributed to a progressive strain deformation of the confining potentials and to the increasing effects of positional disorder in denser dot ensembles. Different relaxation mechanisms become predominant in isolated and interacting QDs. The importance of carrier recapture into the QDs is reduced as the dot separation increases, resulting in very different behaviors of the PL energy shifts, PL intensities, and degree of inhomogeneous line-width broadening as a function of temperature. The latter observation is attributed to inhibited carrier capture into the QDs due to temperature dependent carrier mobility in the GaAs barrier and InGaAs wetting layer [4]. Low temperature carrier trapping at potential fluctuations in the wetting layer (WL) might be explained by Indium enrichment found in ternary InGaAs QDs [5] in terms of alloy variations in the Wetting Layer.

The PL emission from InGaAs/GaAs quantum-well (QW) and quantum-dot (QD) structures were also compared after controlled irradiation with 1.5-MeV proton fluxes, showing a significant enhancement in radiation tolerance with three-dimensional quantum confinement. Some additional radiation-induced changes in photo-carrier recombination from QDs, include a slight increase in PL emission with low and intermediate proton doses [6]. Reduction of

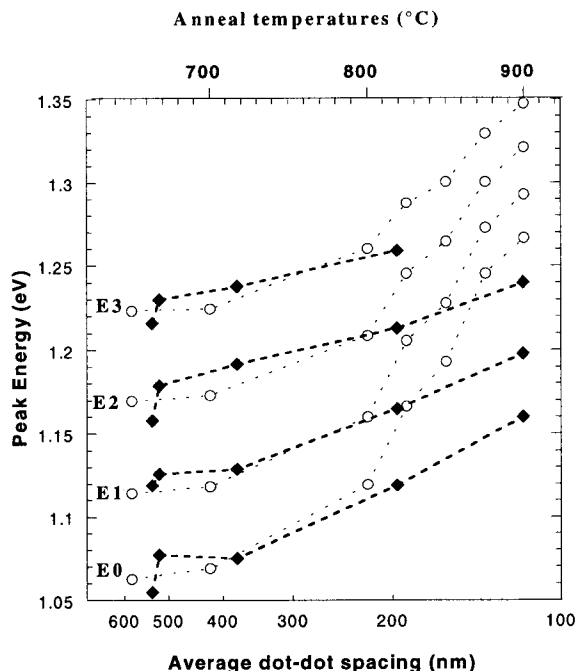


Fig. 1. Level energies vs average dot-dot separation (solid diamonds) [2], compared with level shifts induced by thermal intermixing (hollow circles) [3] obtained from InGaAs/GaAs QD ensembles.

the phonon bottleneck by defect assisted phonon emission which has been proposed [7] as a mechanism to explain the bright PL emission in QDs could explain this surprising effect. Defects introduced by proton induced displacement damage could provide additional relaxation paths for thermalization of carriers and increase the luminescence emission. The impact of these findings on QD based device applications will be discussed.

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